CHAPTER 4

ENVIRONMENTAL CONSIDERATIONS IN CONSTRUCTION, OPERATION, AND MAINTENANCE

4-1. Dredging and Dredged Material Disposal.

a. General. Dredging and dredged material disposal are major activities involved in construction, operation, and maintenance of deep-draft navigation projects. Sediments dredged from new channels consist of material that was deposited by natural processes, often before the appearance of modern man, and may have chemical and engineering properties that create fewer environmental problems than material from maintenance projects. Material removed during maintenance dredging of navigation channels is an accumulation of unconsolidated soil particles that have been transported by wind and water. It is a soil with potential beneficial use. However, material from maintenance dredging may contain a variety of contaminants contributed by man's activities. Equipment selection for dredging is discussed in paragraph 3-5c and EM 1110-2-5025. This section is concerned primarily with dredging and dredged material disposal activities during maintenance of deep-draft navigation projects.

b. Sediment Resuspension During Dredging.

(1) General. There are now ample research results indicating that sediment resuspension during dredging does not result in significant water quality degradation. It has been demonstrated that elevated suspended solids concentrations are generally confined to the immediate vicinity of the dredge and dissipate rapidly at the completion of the operation. However, in cases where sediment resuspension must be minimized, equipment and operational techniques can be selected to meet this requirement. The cutterhead dredge seems to have the least effect on water quality during the dredging operation. This is followed by the hopper dredge, without overflow. When used during overflow periods, the clamshell bucket dredge and hopper dredge can both produce elevated levels of suspended solids in the water column. Sediment resuspension levels during dredging can be reduced by modifying equipment and operating techniques. Both the type of equipment and the operating techniques used with the equipment are important. This section presents some of the commonly used dredges and their potential for causing sediment resuspension during operations.

(2) Cutterhead dredges. The cutterhead dredge is basically a hydraulic suction pipe combined with a "cutterhead" to loosen material that is too consolidated to be removed by suction alone (Figure 4-1). While the properly designed cutterhead will efficiently cut and guide the bottom material toward the suction, the cutting action and turbulence associated with the rotation of the cutterhead will resuspend a portion of the bottom material. Within 10 feet of the cutterhead, suspended solids concentrations are highly variable, but may be as high as 10 to 20 grams per liter. Near-bottom suspended solids concentrations may be elevated to levels of a few hundred milligrams per liter at distances of 1,000 feet from the cutterhead. Factors influencing sediment resuspension during cutterhead dredging include the type of material, thickness of cut, rate of swing, cutterhead rotating speed, and cutterhead design. The shape of the cutterhead also affects the sediment resuspended, particularly if no "over-depth" is allowed. The cutterheads shown in Figure 4-2 have the

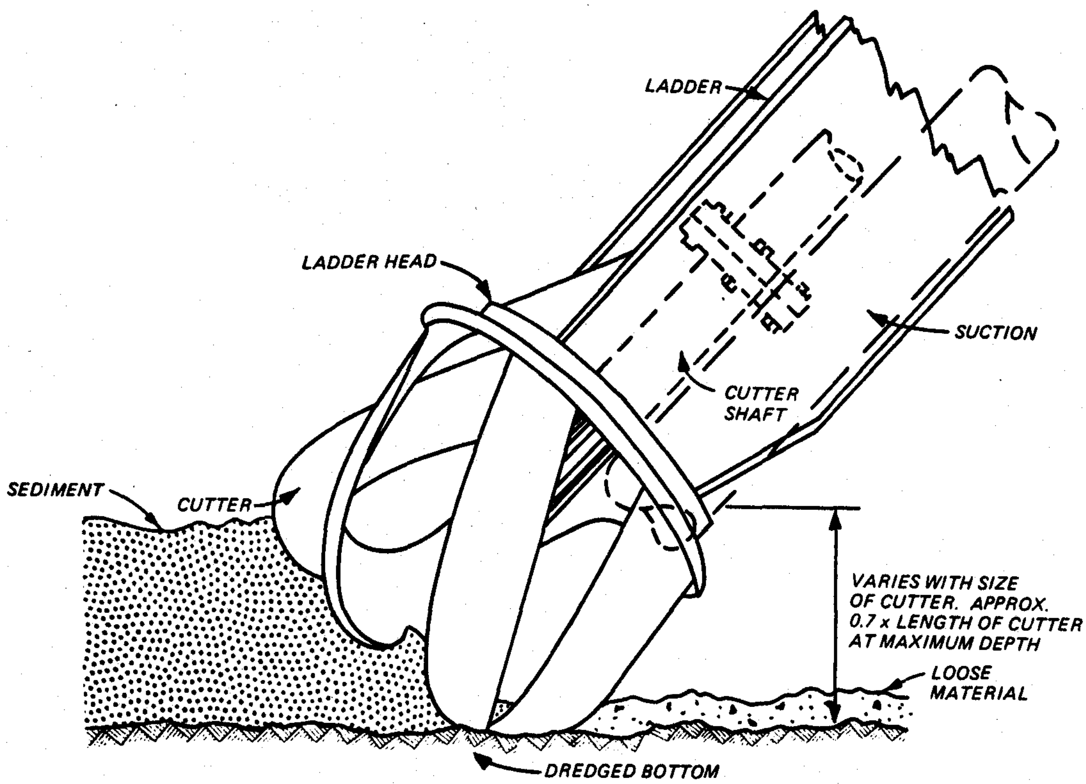

Figure 4-1. Hydraulic cutterhead

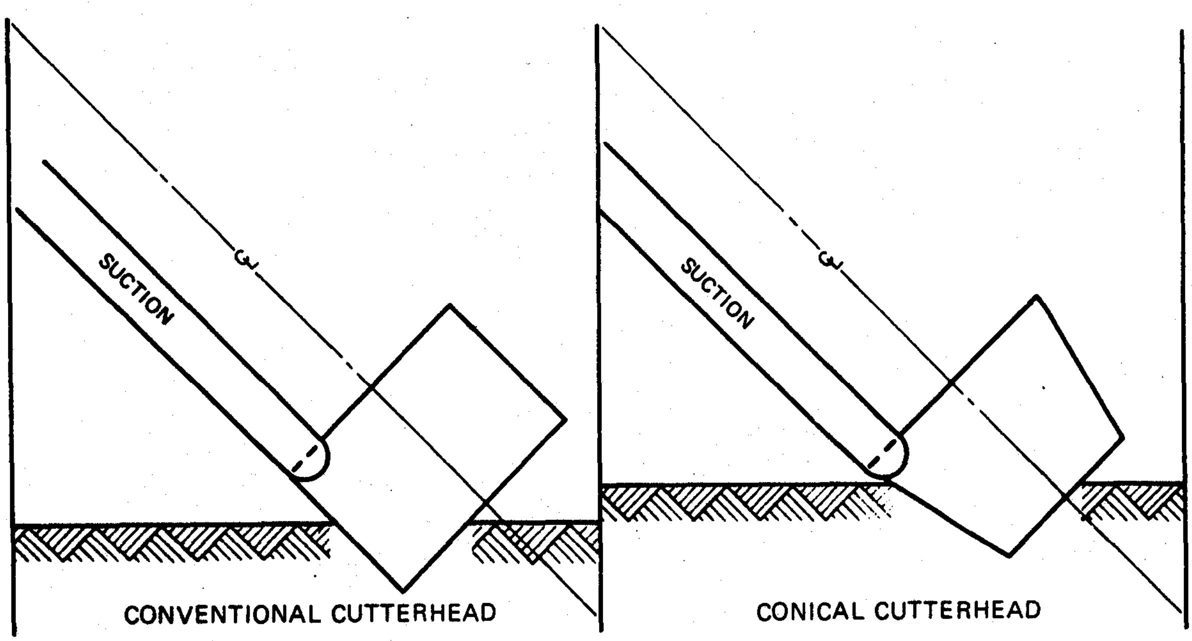

Figure 4-2. Examples of cutterhead designs

same length and base width. They are also depressed to the same angle and are buried to the same depth. However, with the conical-shaped head, the suction is brought closer to the material and the chance of entrainment is improved. This shape difference would be particularly important if the head was not completely buried. The angle α in Figure 4-3 is called the rake angle. If the rake angle is too large, it will cause a gouging action that will sling soft, fine-grained material outward. If the rake angle is too small, heeling (the striking of the bottom with the heel of the tooth) will occur and increase resuspension. For fine-grained maintenance-type material, a small rake angle of from 20 to 25 degrees would be best. This would allow a shallow entry that would lift the bottom sediment and guide it toward the suction.

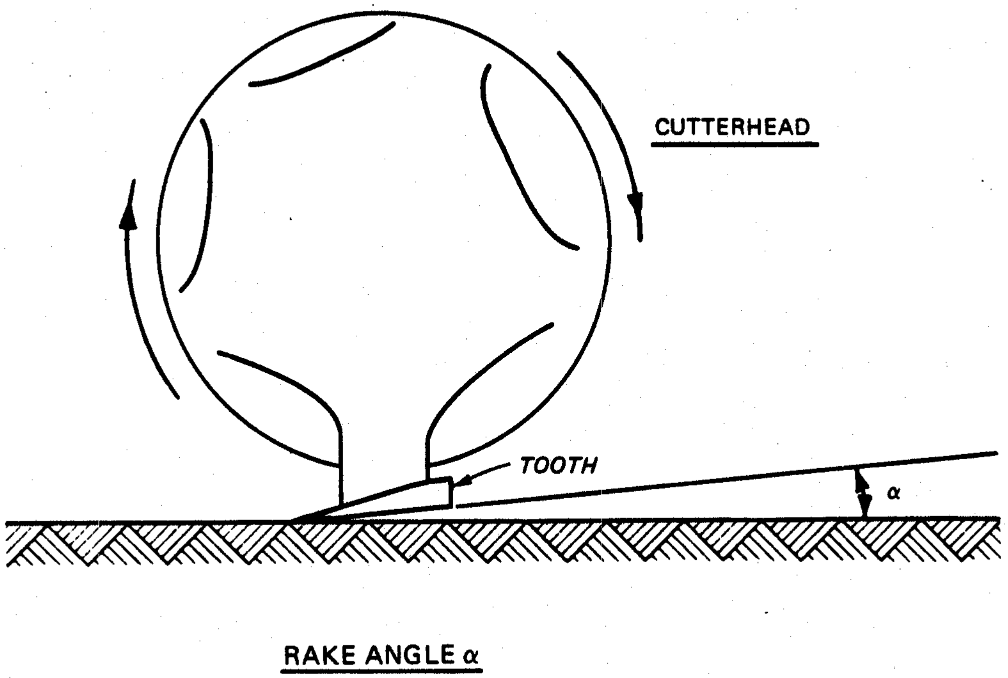

Figure 4-3. Rake angle of cutters on cutterhead

(3) Hopper dredges. Hopper dredges are used mainly for maintenance dredging in deep-draft harbor areas and shipping channels where traffic and operating conditions rule out the use of stationary dredges (Figure 4-4). During filling operations, pumping of the dredged material slurry into the hoppers is often continued after the hoppers have been filled in order to maximize the amount of high-density material in the hopper. The low-density turbid water at the surface of the filled hoppers then overflows and is usually discharged through ports located near the waterline of the dredge. Resuspension of fine-grained maintenance dredged material during hopper dredge operations is caused by the dragheads as they are pulled through the sediment, turbulence generated by the vessel and its prop wash, and overflow of turbid water during hopper-filling operations. Field data confirm that the suspended solids levels generated by a hopper dredge operation are primarily caused by hopper overflow in the near-surface water and draghead resuspension in near-bottom water. In the immediate vicinity of the dredge, a well-defined upper plume is generated by the overflow process and a near-bottom plume by draghead resuspension; 900 to 1200 feet behind the dredges, the two plumes merge into a single plume

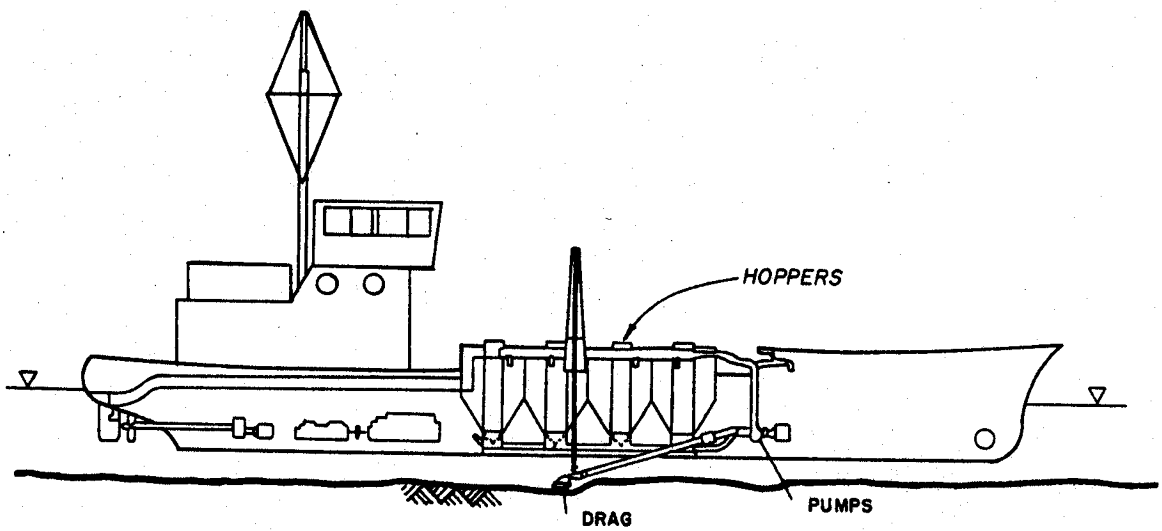

Figure 4-4. Seagoing hopper dredge

(Figure 4-5). As the distance from the dredge increases, the suspended solids concentration in the plume generally decreases, and the plume becomes increasingly limited to the near-bottom waters. Suspended solids concentrations may be as high as several tens of grams per liter near the discharge port and as high as a few grams per liter near the draghead. Suspended sediment levels in the near-surface plume appear to decrease exponentially with increasing distance from the dredge due to settling and dispersion, and the levels quickly reach concentrations of less than one gram per liter. However, plume concentrations may exceed background levels even at distances in excess of 3600 feet. Of the two sources of sediment resuspension from the hopper dredge (the draghead and pumping past overflow), the overflow material produces by far the most sediment resuspension. This source of near surface resuspension can be addressed in several ways. The first is to assess the type of material being dredged and its environmental impact. If the material being dredged is clean sand, the percentage of solids in the overflow will be small, and economic loading may be achieved by pumping past overflow. When contaminated sediments are to be dredged and adverse environmental effects have been identified, pumping past overflow is not recommended. In such cases, other types of dredges may be more suitable for removing the contaminated sediments from the channel prism. In the case of fine-grained materials, the settling properties of silt and clay sediments may be such that only a minimal load increase would be achieved by pumping past overflow.

(4) Bucket dredges. The bucket dredge consists of various types of buckets operated from a crane or derrick mounted on a barge or on land. It is used extensively for removing relatively small volumes of material, particularly around docks and piers or within restricted areas. The sediment removed is a nearly in situ density; however, the production rates are quite low compared with those of a cutterhead dredge, especially in consolidated material. The dredging depth is practically unlimited, but the production rate drops with an increase in depth. The bucket dredge usually leaves an irregular cratered bottom. The resuspension of sediments during bucket dredging is caused primarily by the impact, penetration, and withdrawal of the bucket from the bottom

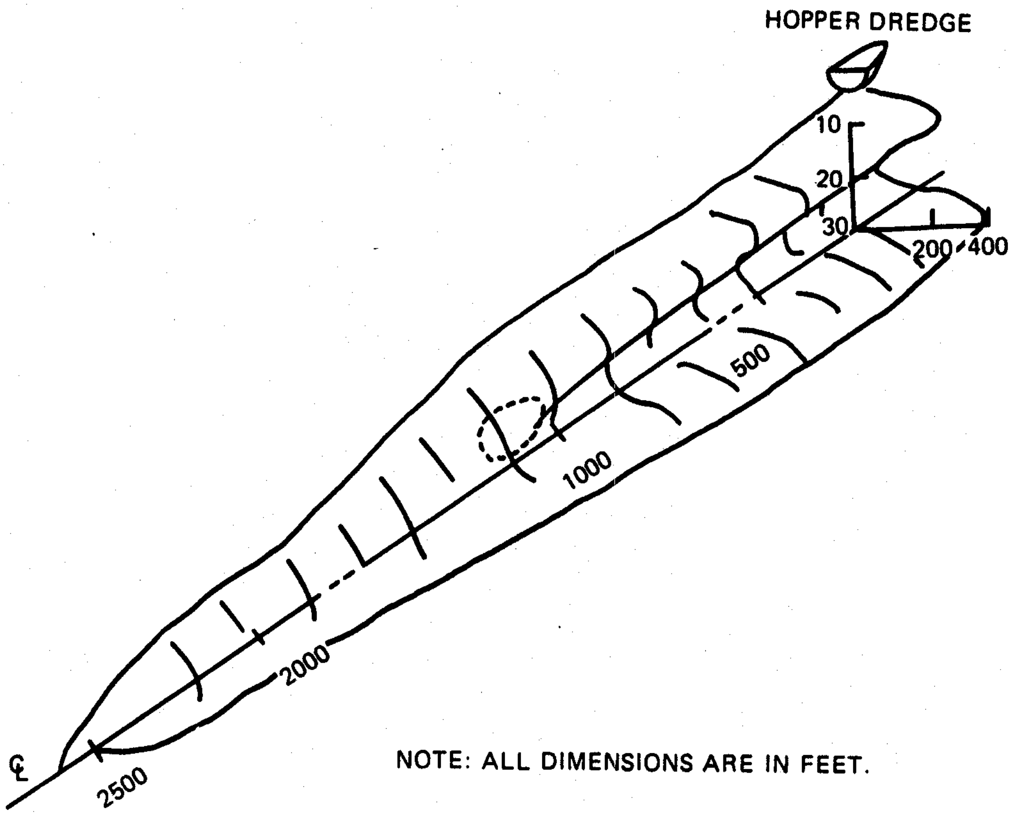

Figure 4-5. Hypothetical suspended solids plume downstream of a hopper dredge

sediments. Secondary causes are loss of material from the bucket as it is pulled through the water, spillage of turbid water from the top and through the jaws of the bucket as it breaks the surface, and inadvertant spillage while dumping (Figure 4-6). Limited field measurements on sediment resuspension caused by bucket dredges showed that the plume downstream of a typical clamshell operation may extend approximately 1000 feet at the surface and 1500 feet near the bottom. It was also observed that the maximum suspended sediment concentration in the immediate vicinity of the dredging operation was less than 500 milligrams per liter and decreased rapidly with distance from the operation due to settling and mixing effects. The major source of turbidity in the lower water column is mainly sediment resuspended at the impact point of the clamshell. Although researchers have reported some reduction in sediment resuspension with the variation of hoist speed and depth of cut, the greatest reduction in resuspension with clamshell dredging came from the use of a so-called "watertight" or enclosed clamshell bucket. The Port and Harbour Institute of Japan developed a watertight bucket with an enclosed top to contain the dredged material within the bucket. A direct comparison of a one-cubic-meter standard open clamshell bucket with a watertight clamshell bucket indicates that watertight buckets generate 30 to 70 percent less resuspension in the water column than open buckets. WES conducted a field test to compare the effectiveness of enclosed clamshell buckets. The resuspension produced by an enclosed 13-cubic-yard bucket (Figure 4-7) was compared with a 12-cubic-yard standard open bucket

Figure 4-6. Spillage from conventional bucket

Figure 4-7. Enclosed 13-cubic-yard clamshell

during dredging of the St. Johns River near Jacksonville, Florida. The results of this test are given in the following tabulation.

Water Column	Radial	Suspended Sediment (mg/ℓ)[1/] Enclosed	Open	Percent Reduction
Upper	1	33.7	76.4	56
	2	27.8	45.8	39
Lower[2/]	1	189.0	84.6	
	2	283.4	85.0	

1/ Averages adjusted for background suspended solids levels.
2/ Measurements made within five feet of bottom.

This test revealed a marked reduction (30- to 45-percent reduction) in sediment resuspension in the upper water column with the enclosed bucket. Some drawbacks were also revealed, however. The enclosed bucket produced increased resuspension near the bottom, probably due to a shock wave of water that preceded the watertight bucket because of the enclosed top. Also, both the earlier Japanese and the Jacksonville buckets had rubber gaskets along the cutting edge of the bucket to seal them. This limited the use of the bucket to soft material and trash-free areas.

c. Open-Water Disposal.

(1) General. The three major open-water disposal methods are: (a) hopper dredge discharge, (b) barge disposal, and (c) hydraulic pipeline disposal. These methods are controlled by the selection of a dredge for a specific dredging project. This section deals with the physical aspects of placing dredged material in open-water disposal sites. The following items must be considered when evaluating the open-water disposal alternative:

Item	Information Source
Open-water disposal	EM 1110-2-5025
Water-column turbidity	WES TR DS-78-13
Fluid mud and mounding	WES TR DS-78-13
Turbidity plume models	WES TR DS-78-13 WES TR DS-78-3

(2) Behavior of discharges from hopper dredge. The characteristics and operation of hopper dredges are discussed in EM 1110-2-5025. When the hoppers have been filled as described, the drag arms are raised and the hopper dredge proceeds to the disposal site. At the disposal site, hopper doors in

the bottom of the ship's hull are opened and the entire hopper contents are emptied in a matter of seconds; the dredge then returns to the dredging site to reload. This procedure produces a series of discrete discharges at intervals of perhaps one to several hours. Upon release from the hopper dredge at the disposal site, the dredged material falls through the water column as a well-defined jet of high-density fluid that may contain blocks of solid material (Figure 4-8). Ambient water is entrained during descent. After it hits bottom, some of the dredged material comes to rest, and some spreads horizontally upon bottom impact and is carried away until the turbulence is sufficiently reduced to permit its deposition.

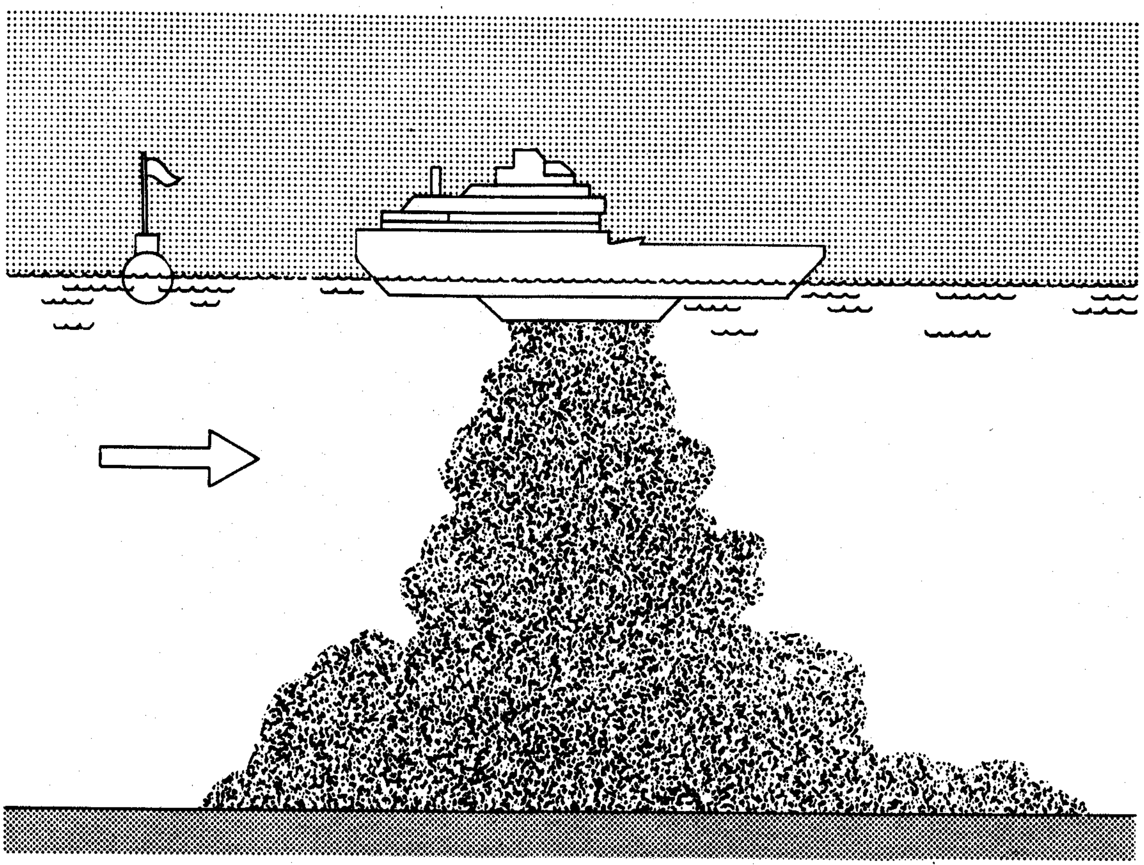

Figure 4-8. Movement of dredged material discharged from a hopper dredge

(3) Behavior of discharges from barge disposal. Bucket dredges remove the sediment being dredged at nearly its in situ density and place it in barges or scows for transportation to the disposal area, as described in EM 1110-2-5025. Although several barges may be used so that the dredging is essentially continuous, disposal occurs as a series of discrete discharges. The dredged material may be a slurry similar to that in a hopper dredge, but often sediments dredged by clamshell remain in fairly large consolidated clumps and reach the bottom in this form. Whatever its form, the dredged material descends rapidly through the water column to the bottom, and only a small amount of the material remains suspended (Figure 4-9).

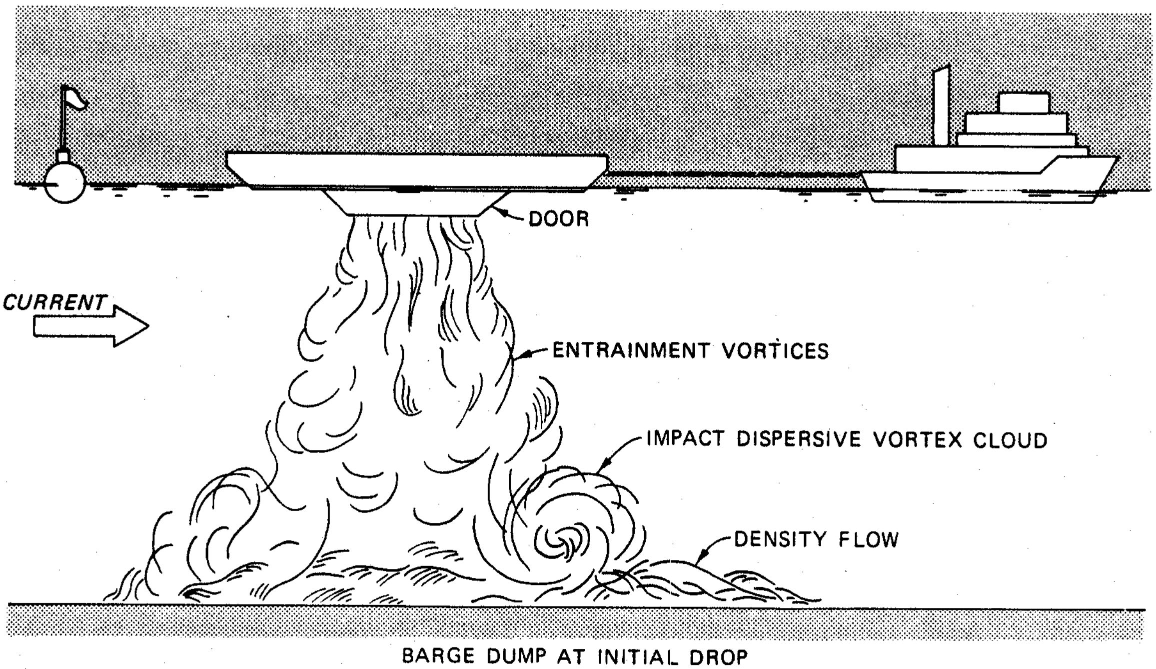

Figure 4-9. Dredged material discharged from a barge

(4) Behavior of hydraulic pipeline discharges. The operation of a cutterhead dredge, described in EM 1110-2-5025, produces a slurry of sediment and water discharged at the disposal site in a continuous stream. As the dredge progresses up the channel, the pipeline is moved periodically to keep abreast of the dredge. The discharged material slurry is generally dispersed in three modes. Any coarse material, such as gravel, clay balls, or coarse sand, will immediately settle to the bottom of the disposal area and usually accumulates directly beneath the discharge point. The vast majority of the fine-grained material in the slurry also descends rapidly to the bottom in a well-defined jet of high-density fluid, where it forms a low-gradient circular or elliptical fluid mud mound. Approximately one to three percent of the discharged material is stripped away from the outside of the slurry jet as it descends through the water column and remains suspended as a turbidity plume (Figure 4-10). During the maintenance dredging of channels located in rivers and estuaries, fine-grained dredged material is typically disposed within designated open-water or side-channel disposal areas located 1000 to 3000 feet from the channel in water depths of 4 to 20 feet. On most large maintenance operations, a cutterhead dredge may be used to excavate the sediment, which is subsequently pumped as a slurry through a pontoon-supported pipeline at velocities of 13 to 20 feet per second to a disposal area adjacent to the channel (Figure 4-10). Due to the variability in depth of cut, rate of swing, and stepping technique used on a particular operation, the dredged material slurry will usually have a highly variable solids content ranging from 0 to 40 percent solids by weight; 15 percent solids by weight is a typical average value. Dissolved oxygen levels in the fine-grained slurry are essentially zero. The end of the pipeline may be either above water or submerged at an angle of 0 to 90 degrees relative to the water surface and may be equipped with a deflector plate. As the dredge advances down the channel, the discharge point is usually

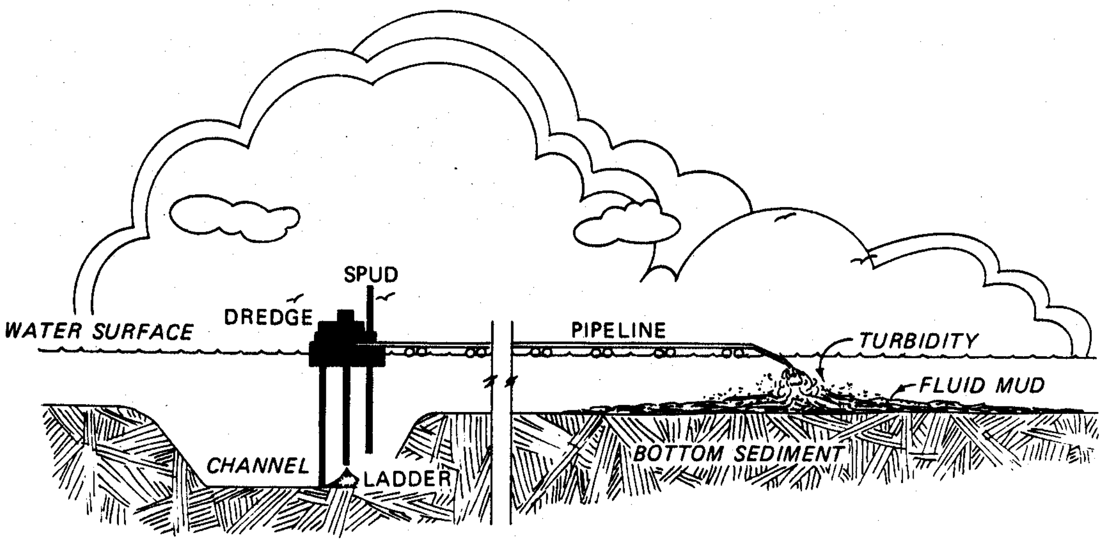

Figure 4-10. Typical channel maintenance dredging operation with open-water pipeline disposal

moved periodically to other disposal areas adjacent to the channel. The dredging operation is normally continuous, but may be interrupted by mechanical breakdown, ship traffic, or bad weather.

d. Confined Dredged Material Disposal.

(1) General. Diked containment areas are used to retain dredged material solids while allowing the carrier water to be released from the containment area. The two purposes of containment areas are: (a) to provide adequate storage capacity to meet dredging requirements, and (b) to attain the highest possible efficiency in retaining solids during the dredging operation in order to meet effluent suspended solids requirements. These considerations are interrelated and depend upon effective design, operation, and management of the containment area. Basic guidelines for design, operation, and management of containment areas are presented in WES TR DS-78-10. Confined disposal of contaminated sediments must be planned to contain potentially toxic materials to control or minimize potential environmental impacts (Figure 4-11). Four major mechanisms for transport of contaminants from upland disposal areas have been identified:

(a) Release of contaminants in the effluent during disposal operations.

(b) Leaching into ground water.

(c) Surface runoff of contaminants in either dissolved or suspended particulate form following disposal.

(d) Plant uptake directly from sediments, followed by indirect animal uptake from feeding on vegetation.

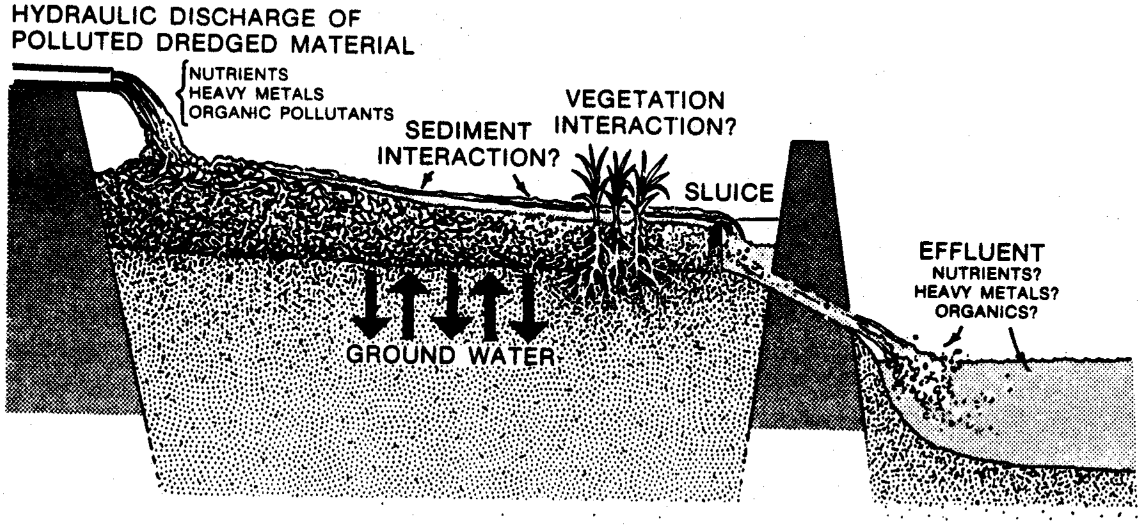

Figure 4-11. Confined disposal area effluent and leachate control

(2) Containment area design. The major components of a dredged material containment area are shown schematically in Figure 4-12. A tract of land is surrounded by dikes to form a confined surface area into which dredged channel sediments are pumped hydraulically. In some dredging operations, especially in the case of new-work dredging, sand, clay balls, and/or gravel may be present. This coarse material rapidly falls out of suspension and forms a mound near the dredge inlet pipe. The fine-grained material (silt and clay) continues to flow through the containment area where most of the solids settle out of suspension and thereby occupy a given storage volume. The fine-grained dredged material is usually rather homogeneous and is easily characterized. The clarified water is discharged from the containment area over a weir. This effluent can be characterized by its suspended solids concentration and rate of outflow. Effluent flow rate is approximately equal to influent flow rate for a continuously operating disposal area. To promote effective sedimentation, ponded water is maintained in the area; the depth of water is controlled by the elevation of the weir crest. The thickness of the dredged material layer

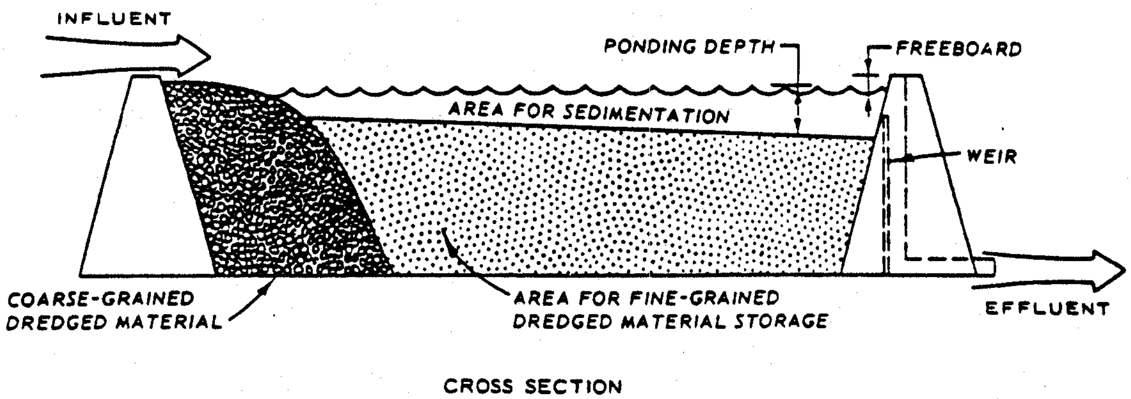

Figure 4-12. Schematic of a dredged material containment area

increases with time until the dredging operation is completed. Minimum freeboard requirements and mounding of coarse-grained material result in a ponded surface area smaller than the total surface area enclosed by the dikes. In most cases, confined disposal areas must be utilized over a period of many years, storing material dredged periodically over the design life. Long-term storage capacity for these sites is influenced by consolidation of dredged material and foundation soils, dewatering of material, and effective management of the disposal area. The following steps should be used for containment area design:

Step	Information Source
Evaluate dredging activities	WES TR DS-78-10
Perform field investigations	WES TR DS-78-10
Perform laboratory investigations	WES TR DS-78-10
Design methods for storage and retention of suspended solids	WES TR DS-78-10
Evaluate long-term storage requirements	WES TR DS-78-10
Design weirs	WES TR DS-78-10
Evaluate chemical clarification requirements	WES TR DS-83-2
Design retaining dikes	WES TR D-77-9

(3) Containment area operation and management.

(a) A major consideration in proper containment area operation is providing the ponding necessary for sedimentation and retention of suspended solids. Adequate ponding depth during the dredging operation is maintained by controlling the weir crest elevation, usually by placing boards within the weir structure. Before dredging commences, the weir should be boarded to the highest possible elevation that dike stability considerations will allow. This practice will ensure maximum possible efficiency of the containment area. The maximum elevation must allow for adequate ponding depth above the highest expected level of accumulated settled solids and yet remain below the required freeboard. If the basin is undersized or if inefficient settling is occurring in the basin, it is necessary to increase detention time and reduce approach velocity to achieve efficient settling and to avoid resuspension, respectively. Detention time can be increased by raising the weir crest to its highest elevation to increase the ponding depth; it may also be increased by operating the dredge intermittently to maintain a maximum allowable static head or depth of flow over the weir, based on the effluent quality achieved at various weir crest elevations. Once the dredging operation is completed, the ponded water must be removed to promote drying and consolidation of dredged material. (WES TR DS-78-10 provides detailed guidance.)

(b) The importance of periodic site inspections and continuous site management following the dredging operation cannot be overemphasized. Once the dredging operation has been completed and the ponded water has been decanted, site management efforts should be concentrated on maximizing the containment storage capacity gained from continued drying and consolidation of dredged material and foundation soils. To ensure that precipitation does not pond water, the weir crest elevation must be kept at levels allowing efficient release of runoff water. This will require periodic lowering of the weir crest elevation as the dredged material surface settles. Gains in long-term storage capacity of containment areas through natural drying processes can also be increased by placing the dredged material in thin lifts. Thin-lift placement greatly increases potential capacity through active dewatering and disposal area reuse management programs. Thin-lift placement can be achieved by obtaining sufficient land area to ensure adequate storage capacity without the need for thick lifts. It requires careful long-range planning to ensure that the large land area is used effectively for dredged material dewatering, rather than simply being a containment area whose service life is longer than that of a smaller area. Dividing a large containment area into several compartments can facilitate management; each compartment can be managed separately so that some compartments are being filled while the dredged material in others is being dewatered. (WES TR DS-78-11 provides detailed guidance.)

e. Habitat Development.

(1) General. Habitat development refers to the establishment of relatively permanent and biologically productive plant and animal habitats. The use of dredged material as a substrate for habitat development offers a disposal technique that is, in many situations, a feasible alternative compared with more conventional open-water, wetland, or confined disposal options. Four general habitats are suitable for establishment on dredged material: marsh, upland, island, and aquatic. Within any habitat, several distinct biological communities may occur. The determination of the feasibility of habitat development will center on the nature of the surrounding biological communities, nature of the dredged material, site selection, frequency with which the site will be used, engineering design, cost of alternatives, environmental impacts, and public approval. If habitat development is the selected alternative, a decision regarding the type or types of habitats to be developed must be made; in general, site peculiarities will usually allow only one or two logical options. References that should be consulted for information on habitat development include:

Item	Information Source
Marsh development	WES TR DS-78-16
Upland habitat	WES TR DS-78-17
Island habitat	WES TR DS-78-18
Aquatic habitat	WES, Environmental Laboratory

(2) Marsh habitat. Marshes are considered to be any community of grasses and/or herbs that experiences periodic or permanent inundation. Typically, these are intertidal fresh, brackish, or salt marshes or relatively permanently inundated freshwater marshes. Marshes are often recognized as extremely valuable natural systems and are accorded importance in food and detrital production, fish and wildlife cover, nutrient cycling, erosion control, floodwater retention, ground-water recharge, and aesthetic value. Marsh values are highly site specific and must be interpreted in terms of such variables as plant species composition, wildlife use, location, and size, which in turn influence their impact upon a given ecosystem. Marsh development has been the most studied of the habitat development alternatives, and accurate techniques have been developed to estimate costs and to design, construct, and maintain these systems. Over 100 marshes have been established on dredged material. The advantages most frequently identified with marsh development are: considerable public appeal, creation of desirable biological communities, considerable potential for enhancement or mitigation, and, frequently, low cost.

(3) Upland habitat. Two situations have potential for upland habitat development. In one, an existing disposal area can be reclaimed or increased in value with a given level of effort. In the other, dredged material disposal from a dredging project will occur at a selected site, and disposal can be planned to meet a habitat goal. The site may be selected for suitability and potential after eliminating alternative sites, but in many cases the choice will be limited and planning will involve making the best of a less than optimum situation. Information provided in WES TR DS-78-17 applies to both situations, with the exception of the steps that deal with the actual disposal process and apply to an active project. It is assumed, in the case of an active dredging project, that habitat development has been selected as the alternative for dredged material disposal. Figure 4-13 outlines procedural guidelines for selection of upland habitat development projects.

(4) Island habitat. Dredged material islands range in size from an acre to several hundred acres. Island habitats are terrestrial communities completely surrounded by water or wetlands and are distinguished by their isolation and their limited food and cover. Because they are isolated and relatively predator free, they have particular value as nesting and roosting sites for numerous species of sea and wading birds, e.g., gulls, terns, egrets, herons, and pelicans. The importance of dredged material islands to nesting species tends to decrease as the size increases because larger islands are more likely to support resident predators. However, isolation is more important than size; thus, large isolated islands may be very attractive to nesting birds. Dredged material islands are found in low- to medium-energy sites throughout the United States. Typically, these are sandy islands located adjacent to navigation channels and are characteristic of the Intracoastal Waterway. In recent years, many active dredged material islands have been diked to improve containment characteristics of the sites.

(5) Aquatic habitats. Aquatic habitat development refers to the establishment of biological communities on dredged material at or below mean tide. Potential developments include such communities as tidal flats, seagrass meadows, oyster beds, and clam flats. The bottoms of many water bodies could be altered using dredged material; in many cases this would simultaneously

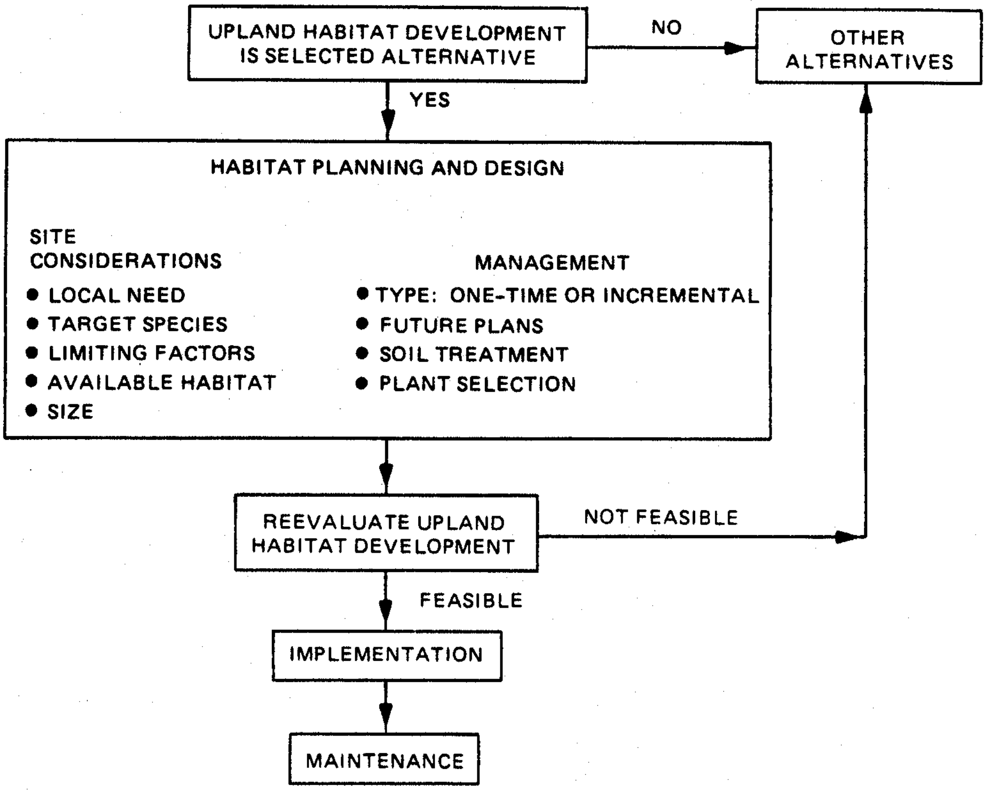

Figure 4-13. Outline of procedural guidelines for selection of upland habitat development projects

improve the characteristics of the site for selected species and permit the disposal of significant quantities of material. Planned aquatic habitat development is a relatively new and rapidly moving field of study; however, with the exception of many unintentional occurrences and several small-scale demonstration projects, this alternative is largely untested. No general texts or manuals are currently available; however, potential users may obtain updated information by contacting the Environmental Laboratory at the WES.

4-2. <u>Navigation Traffic</u>. Possible means to alleviate adverse environmental effects of navigation traffic include:

a. Encouraging pilots to keep vessels within the normal navigational channel.

b. Setting up established fleeting areas for commercial traffic.

c. Maintaining environmentally sensitive areas (e.g. fish nursery areas or riverine areas near heron rookeries) off limits to traffic.

d. Restricting the speed, horsepower, and/or frequency of boat traffic. Table 4-1 depicts the relationships among vessel and wave parameters.

e. If habitat destruction due to vessel-caused wave erosion is a problem, structures (paragraph 3-4) to protect environmentally sensitive areas

Table 4-1. Typical Waves from Representative Vessels*

Vessel	Speed ft/sec	Length feet	Draft feet	Breadth feet	Gross tonnage	Draw-down feet	Wave Height feet
	UP						
1	16.0	690	29	85	25,600	1.0	0.75
2	18.6	465	29	60	5,900	0.5	1.0
3	14.8	537	29	69	11,300	1.0	0.5
4	13.0	297	18	43	2,000	0.75	1.5
5	17.5	505	28	62	9,000	0.5	0.5
6	21.0	400	20	52	3,100	0.25	1.5
7	16.0	730	27	75	15,700	1.25	0.75
8	18.7	467	28	63	8,500	0.75	1.5
9	14.0	523	27	68	10,600	1.0	0.75
10	19.7	412	25	60	5,100	0.75	1.0
11	19.0	500	28	63	7,700	1.00	1.5
	DOWN						
12	25.5	608	29	80	23,000	3.0	1.0
13	27.0	374	24	51	4,500	0.75	1.5
14	23.0	519	30	65	10,800	0.75	0.75
15	24.0	516	27	65	7,300	0.5	1.0
16	24.0	291	19	45	2,500	0.5	1.25
17	28.0	467	28	59	8,200	1.0	2.5
18	25.0	608	29	80	22,000	2.5	1.5

ft/sec	10	12	14	16	18	20	22	24	26	28	30
knots	5.9	7.1	8.3	9.5	10.7	11.8	13.0	14.2	15.4	16.6	17.8

* Distance to sailing line approximately 700 feet.
Source: Hurst and Brenner (1969).

such as shorelines and marshes may be evaluated. (Hurst and Brenner (1969), Mulvihill et al. (1980), and Schnick et al. (1982) provide more detailed information.)

f. Maintaining traffic inside the navigational channel and keeping selected areas off limits are both feasible but would involve the cooperation of several agencies and groups.

g. Presently, the best means to improve navigation effects would be to maintain habitat diversity and to protect productive habitats, as discussed in paragraph 3-4.